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1.0 DESCRIPTION OF EXPERIMENT

1.1 Introduction

We have completed and successfully flown the normal incidence X-ray telescope (NIXT) designed for very high spatial resolution studies of the solar corona. The telescope has been designed to fly on a Terrier/Black Brandt vehicle, and makes use of multilayer coatings to achieve usable reflectivity in the soft X-ray regime. The fifth flight of this telescope occurred July 11, 1991 at 1726 hours UT as part of an eclipse experiment. With this flight, we reached our design goal of 1/2 arc-second spatial resolution.

The primary reason for using multilayer coatings at XUV and soft X-ray wavelengths is because no single surface layer coating can provide acceptable reflectivity at wavelengths shorter than ~300Å when used at normal incidence. For instance, at 173Å the best materials have R~.001. However, by precise deposition of 50 alternating layers of Mo and Si, mirrors with R~50% have been produced. When normal incidence mirror designs are employed, the immediate advantage is greatly improved image quality. The NIXT telescope recorded the highest resolution solar corona photographs ever taken on its last three flights. With the improvements now under way, we expect to improve on that performance.

1.2 Science Goals

The experiment has two purposes associated with a single scientific goal. We are trying to obtain high spatial resolution images of the solar corona and to develop a two-dimensional imaging detector sensitive to X-rays and XUV radiation.

The overall purpose is to study activity in the solar corona with sufficient spatial, spectral, and temporal resolution to understand the physical mechanisms responsible for coronal heating and dynamics.

Our analysis of NIXT and **YOHKOH** SXT data from the simultaneous observations carried out in April 1993, shows that the coronal structures seen in the two instruments can be totally different: loops seen in Fe XVI are not visible at all in Fe XVII, and vice versa. Our goal in designing the TXI has therefore been to observe all of the successive ionization stages of a single element (Fe), so that the plasma has nowhere to hide. By tuning through the range of x-ray wavelengths, and combining all of the observed ionization stages, we will build up a complete characterization of the corona in the temperature range covered (log T = 5.8 - 6.4). The TXI design also allows detection of plasma flows by a suitable positioning of the monochromator passband, and detection of polarization of the x-rays via a 90° rotation of the instrument about the line-of-sight direction.

1.3 Scientific Uses and Expected Performance

The results from our last three NIXT flights and recent measurements of X-ray multilayer performance have shown that true sub-arc-second resolution combined with usable reflectivity are now realistic possibilities in a space instrument. We are thus in a position to begin implementing a qualitatively new kind of observing program for solar coronal studies.

The major strength of the multilayer technique will be evidenced when several sets of mirrors are flown at the same time, each one tuned to a different portion of the spectrum. This will allow simultaneous imaging and spectroscopy for both qualitative and quantitative analysis. Alternatively, at wavelengths longer than ~100Å, where the multilayers have sufficient bandwidth, the addition of a dispersive element, such as a double-reflection monochromator will permit the same type of diagnostics to be carried out. At the present time we anticipate three major areas of solar studies in which the rocket instrument will have an immediate impact:

1. **Fine Structure of Coronal Loops.** Present observations are insufficient to constrain theoretical parameters in studies of the heating and dynamics of the hot ($>10^6$K) plasma-filled magnetic structures that are found in the corona. At this time we do not know the radiant temperature and density structure within these loops, the magnitude of coherent plasma flows within them, or the relative importance of transient vs. steady-state heating processes. Additionally, the possible presence of isolated magnetic islands within a loop may be amenable to observation at the higher spatial resolution that we expect to achieve.

2. **Flare Onset and Reconnection.** At the sub-arc-second level of resolution, the possibility exists, particularly in the large-scale class of solar flares known as prominence eruptions, that we may be able to directly image the reconnection regions in which magnetic flux is annihilated and converted to the energy that powers a flare. In a sense these reconnection boundary layers are purely theoretical constructs, since they have not been observed on the Sun. Predicted sizes begin about one order of magnitude below present observational capabilities. Thus, with

the order of magnitude improvement in image quality we may begin to resolve these questions.

3. **Emerging Magnetic Flux.** X-ray studies from Skylab showed that most of the magnetic flux emerging from the solar interior is in small scale "shredded" or intermittent form. The overall balance between large active regions and small emerging flux regions is a function of phase in the solar cycle and is such that the total amount of magnetic flux emerging is nearly constant; the solar cycle can thus be visualized as an oscillation in the wave number distribution of emerging flux.

This observational constraint on magnetic dynamo theories remains to be tested on smaller spatial scales. Previous limitations due to the instrumental resolving power have left undecided the question of how much flux emerges at scale sizes below ~10 arc-seconds. It is certain that at some small spatial scale, magnetic diffusion will dominate so that the size spectrum of emerging flux will be cut off. However, the presently observed spectrum is such that the integrated contribution of small regions increases in importance down to the observational limit. If we are able to observe the turnover at spatial scales obtainable by this new instrumentation, then we will be able to directly test theories for magnetic flux emergence and diffusion.

1.4 Scientific Investigation: Flight Results

The most readily observable manifestation of a solar flare is a brightening in $H\alpha$ of a well-defined area of the Sun. Although there is now general agreement that the energy release takes place in the corona, explaining chromospheric observations is of capital importance for any model of the physical processes that takes place in a flare.

A two-ribbon flare appears in $H\alpha$ as the brightening of two parallel ribbons separated by a dark filament of rising coronal matter. The standard picture calls for some kind of catastrophic instability, either triggered by the shear of the field lines induced by the motion of the footprints in the photosphere, or generated by the interaction of the field and the current flowing in the filament (Van Tend and Kuperus, 1978 and Martens and Kuin, 1989). Reconnection of field lines then occurs beneath the rising filament with the magnetic energy released in the current sheet being transported down to the chromosphere either by a beam of particles or by heat conduction (or both) along the flux tubes.

In 1989 and 1991 we used real-time satellite data combined with a t-2 minutes launch hold, which is called a flare-wait mode. This allowed us to launch during the rise phase of a solar flare. This mode of operation was highly successful in that we obtained extremely good X-ray data at the peak of a solar two-ribbon flare. We also had the good fortune to observe the start of another separate flare event during our flight. The data obtained in the September 11, 1989 flight have provided a totally new view of solar flares in the corona, and do not fit any present theoretical model of how flares occur. Our data are thus presenting a challenge to flare theorists by forcing reexamination of the models.

For flight 36.151 the launch date will be determined by the presence on the Sun of at least one active region with well-developed sunspots. This can be predicted with a ~50% confidence one solar rotation (~27 days) in advance, and can be known with high confidence (>90%) three days in advance. Thus, a tentative launch date can be set one month prior to launch, and a go/no-go decision can be made 3 days prior.

2.0 SYSTEM DESCRIPTION

2.1 Electronic Systems and Telemetry

The Electronic system has three prime functions:

1. Control the operation of two CCD detectors. This would include the exposure and readout sequencing.
2. Control the operation of the TXI monochromator for wavelength selection and control the indexing of aperture mask on the calibration telescope.
3. Control the command and housekeeping operation.

The electronic design will utilize two on-board computers, one for the prime science operation, and the second for the command, housekeeping, and monochromater operation. The Image Processing Computer (IPC) is based around a Teknor 166Mhz pentium Single Board Computer (SBC) running on a passive PCI bus backplane. This SBC will control the image acquisition of both CCD detectors.

The detector on the tunable x-ray imaging side is being designed by the instrument's co-investigators at the Max Planck Institute. It is an image intensified detector based on a Kodak 2k x 2k CCD. The detectors pixel size is 15 microns^2.

The detector on the XUV telescope side is being designed by SAO. It is based on a Site 1k x 1k back-side illuminated CCD. The detectors pixel size is 24 microns. It will be cooled by a thermal electric cooler (TEC) operating against a passive cold-block. The cold-block is designed to have sufficient energy to cover the flight plus up to 1.5 hours of hold time.

In a pre-programmed sequence, the IPC will initiate exposures and transfer the image data (after appropriate processing and formatting by two dedicated PCI bus frame grabber boards) to the rocket telemetry interface, for transmission to the ground by two 10Mbit data downlinks, and to an on-board storage device, for post-flight retrieval. The housekeeping will use a ISA computer bus backplane, and will use off-the-shelf data acquisition boards from National Instruments operating under LabView software.

The TXI block diagram number TXI-5100, shows the TXI electronic system. The command telemetry, data telemetry, telemetry interface, flight battery, and video telemetry are supplied by NASA. The experiment will be powered by a 28V battery. The power requirements are 28 volts @ 15 amps steady state, 20amps peak for 1 second. NASA will provide and service the batteries. A latching change-over relay will switch the experiment between external and internal power. The experiment's battery power will be applied a few minutes before launch. External power will be used for all testing excepting flight system testing.

The TXI telemetry Requirements are the following:

Command Uplink
1. One RS232 serial command link
2. Six Auxiliary set/reset for manual control
3. Three Momentary pulse commands

Downlink for Science data
1. Two 10Mb/sec WFF93 High Rate PCM Encoders (Sixteen bits and strobes)

Downlink for Housekeeping
1. One RS232 serial encoder
2. Four 10bit digital words and strobes
3. Thirty two Analog (0 to 5V)
   One TV transmitter for the H~Camera

Blockhouse (pre-flight operations)
1. 20 Umbical lines between the blockhouse and experiment for pre-launch check-out.

TABLE 2.1 - LATCH COMMANDS

SAO FUNCTION	SPARCS NOMENCLATURE
MANUAL MODE SET Lock out Automatic Sequence Enable Manual Mode	Aux-2 Set
MANUAL MODE RESET Return to Automatic Sequence Disable Manual Mode	Aux-2 Reset
START EXPOSURE Manual Mode (shutter open)	Aux-3 Set
END EXPOSURE (shutter close- read camera)	Aux-3 Reset
RESTART (terminate exposure in progress)	Aux-4 Set
Return to normal sequence	Aux-4 Reset
SPARE	Aux-5 Set
SPARE	Aux-5 Reset
SPARE	Aux-6 Set
SPARE	Aux-6 Reset
MASTER RESET ENABLE	Aux-7 Set
MASTER RESET DISABLE	Aux-7 Reset
MASTER RESET COMMAND	Momentary 1 (Pulsed)
CAMERA RESET COMMAND	Momentary 2 (Pulsed)
SPARE	Momentary 3 (Pulsed)

2.2 Optical Systems

2.2.1 TXI Experiment

The TXI experiment's optical system is an on-axis design which employs two flat (multi-layer coated) fold mirrors arranged to make an X-ray Monochromater of the Cowan-Golovchenko (Mills and King 1983; Craig *et al.* 1988) arrangement. In this arrangement, the two flat mirrors allow the entrance and exit beams to remain fixed, while the wavelength is changed by their rotation. The exit beam is directed to a spherical telescope mirror which focuses the solar image onto a CCD Detector by passing the beam through a central hole in the second flat mirror. This allows the telescope mirror to be used on-axis thereby minimizing optical aberrations. The optical system is described on SAO drawing TXI-002, Titled: Optical schematic - TXI.

2.2.2 Calibration Telescopes

There are four calibration telescopes of identical design, excepting their coatings which set their wavelength bandpass. The telescopes all share a common detector where only one telescope is imaged at a time. An indexing mask with one open aperture provides the telescope selection while covering the entrance apertures of the non-active telescopes. The optical configuration is a spherical telescope mirror tilted one degree to the incoming beam that focuses the solar image on a CCD detector; SAO drawing TXI-003, Titled: Optical schematic-Calibration experiment describes the optical system. The four telescope mirrors are equally spaced on a circle centered about the detector. This allows the tilt angle to be uniform for all telescopes and minimizes the tilt angle. The system focal ratio is such that the image tilt on the detector is well within the depth of focus so that no image degradation is observed.

2.2.3 H-Alpha Camera

A precision Day-Star Corporation Hydrogen Alpha ($H\alpha$) filter unit having a narrow bandpass (~0.6Å) centered on the $H\alpha$ line (6563.28Å) with a 2.5 cm aperture was selected as the filter. The filter is placed behind a 712.6 millimeter (two lens) EFL telephoto lens system which images the full Sun on a Sony Electronics model XC-77 CCD video camera. The optical path is straight and un-vignetted. The H-Alpha Camera is mounted to the TXI optical bench and aligned parallel to TXI experiment. A similar system was flown successfully on all the NIXT rocket flights and proved that adequate sensitivity can be attained to record the Hα image with sufficient resolution to allow sunspot recognition for aspect determination. This new Camera system has higher resolution coverage and will produce extremely sharp, highly contrasted images which will make pointing confirmation achievable.

2.2.4 SPARCS Pointing Sensors

The TXI telescope will be pointed and stabilized on the Sun by a SPARCS pointing and control system including a RIG (Roll Stabilization Gyro) unit. No attempt is made here to describe the SPARCS system; however, the MASS and LISS Sensors mounting, and co-alignment both to each other and to the TXI telescope will be described.

The MASS sensor is mounted by a rigid bracket attached directly to the rocket vehicle in the WIFF vacuum door assembly. The MASS Sensor is located on the +Z axis (285°) so that its control axes are properly aligned to the vehicle's axis within ±2° per Lockheed-SPARCS Group's instructions. It is positioned 200 mm radially outward from the vehicle's X-X axis and 25 mm back from the leading edge of the separation flange. This positioning guarantees a full unobstructed 70° FOV cone for the sensor.

The LISS (Fine Sun Sensor) assembly is mounted to the TXI's optical bench and positions the sensing element on the rocket's central axis, thereby yielding the largest unobstructed field of view. The control axes (pitch, yaw) of the LISS sensor are aligned within ±1° of the control axis per the Lockheed-SPARCS Groups instructions. The LISS will also be placed behind an aperture stop that only allows the optical beams to pass and thereby shields all other components from being illuminated by the solar beam.

The sensors will be aligned to the TXI telescope either by centering using an auto-collimation telescope to the TXI's focal plane and then erecting the sensors orthogonal to it by standard auto-collimation techniques or by centering a solar image on the TXI focal plane and then using the SPARCS pin hole target.

2.3 Mechanical Systems

2.3.1 Telescope Design

The major mechanical design consideration is the ability to achieve proper optical alignment and positioning of the optical elements including the detectors, while not introducing optical distortions or displacements from either mechanical or thermal stressing. This requirement must be satisfied for two environments. The first is in the laboratory where optical fabrication, testing, image evaluation and correction are performed. This laboratory environment is also roughly equivalent to what is expected during pre-launch activities. The second environment is the rocket flight. The rocket vehicle delivers severe vibration, shock and thermal loads to the experiment during its engine burn phase. The effect of these loads must be accounted for to ensure a successful experiment. The environmental design parameters are stated in Table 2-2, below.

TABLE 2-2 DESIGN PARAMETERS

PARAMETER	LABORATORY	LAUNCH
Temperature 72°F	±10°F	±3°F
Vibration	3.0g rms (3-400 Hz) all axes	19.1g rms (20-2000 Hz) all axes
Shock/Transient	3.0g decaying to 0 in 6 cycles	25g decaying to 5 g in 4 cycles

The design developed must satisfy these parameters. The experiment makes a kinematic attachment to the rocket vehicle at the main structural joint used to join rocket skin sections 3 and 4 together. This attachment comes from the central housing which contains a rigid platform used to house the Monochromator assembly and the experiment's two X-ray detector heads and their preamplifier electronics. This platform forms an optical bench for these components while also providing an interface for a conical tube made from Titanium. The Titanium tube has a sufficiently low Coefficient of Thermal Expansion (CTE) to guarantee that the telescope mirrors mounted to its end flange will remain in sharp focus over the expected temperature range while its conical shape provides rigid structural support. All five telescope (TXI plus 4 Cal.) mirrors mount to the end flange and incorporate the necessary motions to align and focus them. The aperture stops for all telescopes are placed immediately next to the WIFF vacuum door on a rigid panel used to light seal the experiment's entrance aperture. The panel is also used to reject the solar thermal input, thereby minimizing thermal distortions within the optical systems. The panel also has an indexing aperture to uncover one Calibration telescope mirror at a time.

2.3.2 Electronics

The electronics, except for the power system are enclosed in two (2) computer enclosures. The enclosures are attached to the vehicle by vibration isolators to attenuate the vehicle dynamics. The electronic section will be pressurized.

2.3.3 Ancillary Systems

The telescopes are enclosed within the rocket vehicle skin sections numbered 2-5 with the ends sealed by a WIFF vacuum door and an aft bulkhead. This forms a vacuum tight enclosure. The WIFF vacuum door assembly allows for automatic opening and closing of the experiment's entrance aperture and provides protection from re-entry heating and dirt. The WIFF door requires a special battery operated unit to recycle the door during ground testing. The vacuum is achieved through an experiment valved pull-away port located in section 4. A standard thermocouple gauge and gauge controller are provided for initial evacuation and pressure monitoring during ground testing. This gauge will be compared with a Datametrics 600 internal flight gauge to determine experiment pressure. The internal gauge is used to determine experiment pressure during the launch and flight phases. The experiment must have a pressure below 1000 microns in order to launch. The gauge output is 0 to 5 volts dc, which corresponds to 1-1000 μ.

2.3.4 Experiment Weight Summary

The experiment weight summary is shown on table 2-3.

2.3.5 Angular Orientations

The experiment angular orientations are shown in Figure 2-1. The axis notations are according to the SPARCS group's drawings for a rail launched vehicle. The X-X axis is the vehicle's central axis with +X towards the motor.

2.3.6 Mass Moments of Inertia

The mass moments of inertia and the products of inertia for all axes are listed in Table 2-4. They are expressed in SI units of Kg-meter^2 and are about the experiment center of gravity (C.G.). The WIFF vacuum door assembly has been included in these calculations.

2.3.7 Center of Gravity

The experiment is composed of five sections having a total length of 127.68 inches, as shown on Figure 2-2. The C.G. location is for the TXI experiment including the WIFF vacuum door. Section 5 has been designed for attachment of ballast and/or trim weights. These weights have not been included in our C.G. calculations because they are intended to be added to trim both the Spin (X-X) axis and/or to position the Center of Pressure, if required. Therefore their positioning within the vehicle is unknown. The WIFF vacuum door assembly is also included in these calculations as it is an integral part of the experiment/vehicle.

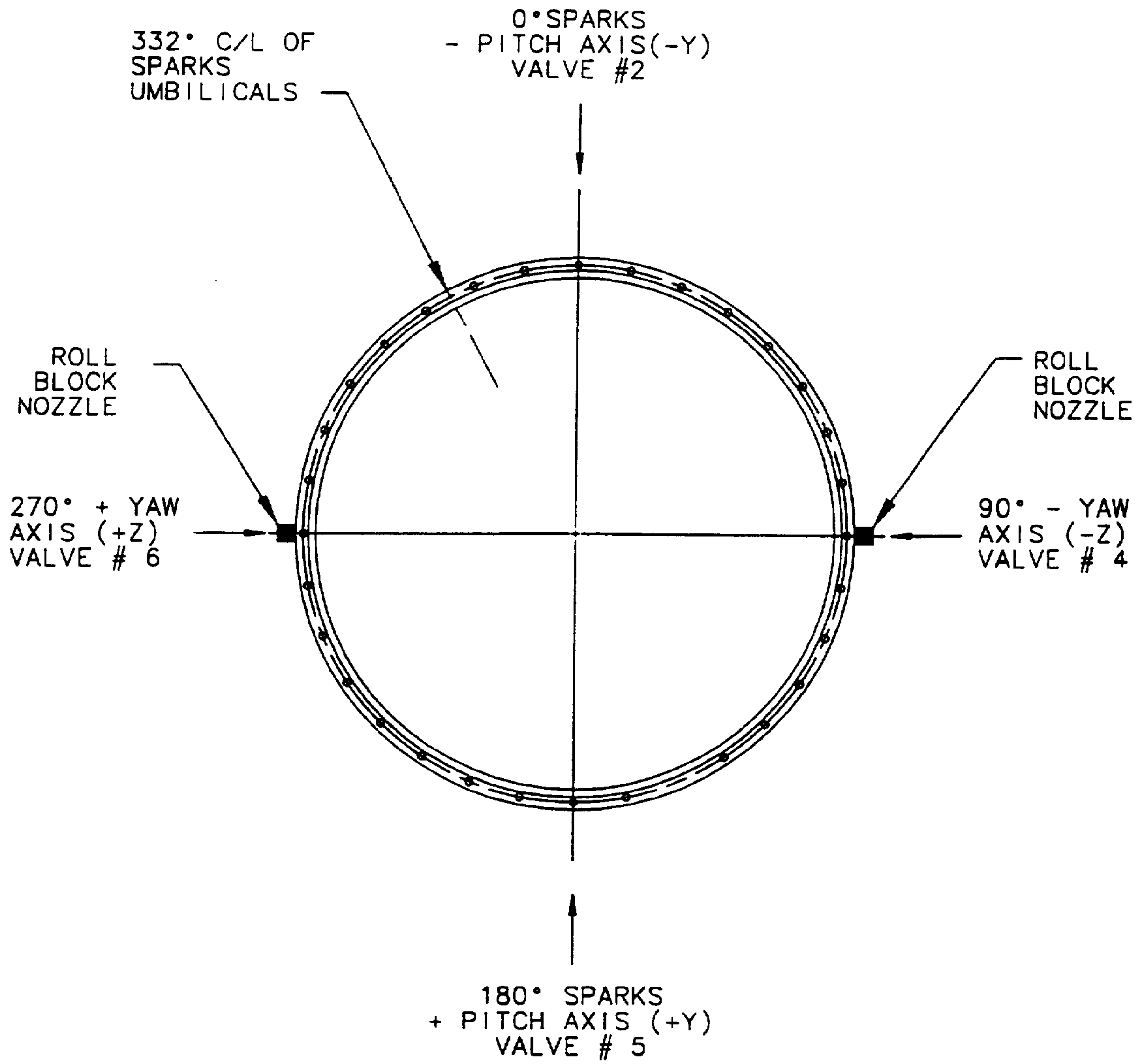


Figure 2-1.
TXI Angular Orientations WSMR-Tower

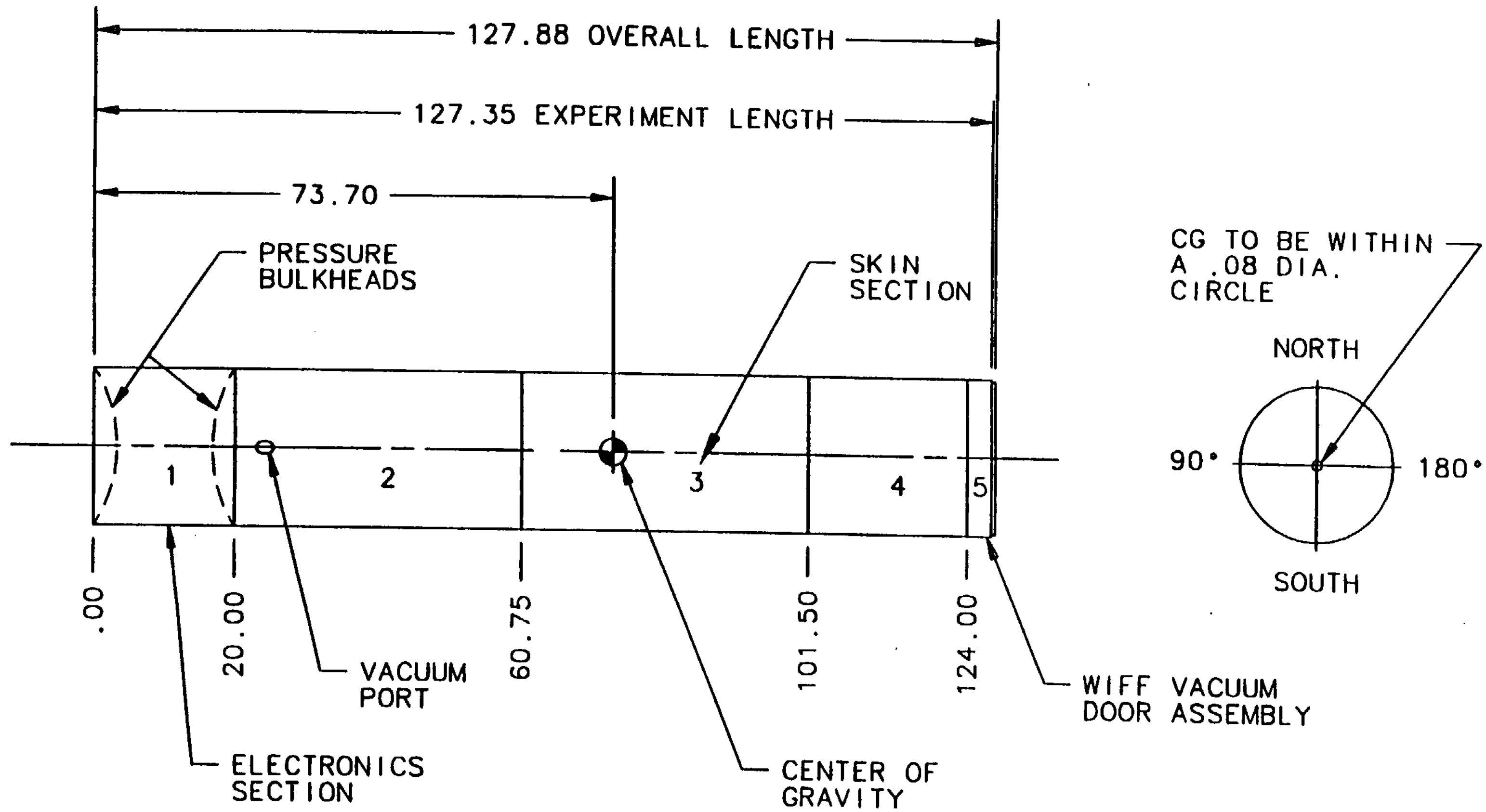


Figure 2-2.
TXI Center of Gravity Location

TABLE 2-3 EXPERIMENT WEIGHT SUMMARY	
COMPONENT DESCRIPTION	WEIGHT (Pounds)
EXPERIMENT	
Experiment Section	
TXI Focal Plane Assembly	41.0
Calibration FP Assembly	28.6
Telescope Tube Assembly	56.5
Forward Aperture Assembly	16.3
Ancillary Equipment	
SPARCS LISS Sensor	2.0
Hα Camera	7.0
Vacuum Gauge and Valve	6.5
Electronics	
Electronics	23.9
Cables, Connectors, Misc.	12.0
TOTAL EXPERIMENT WEIGHT	194.5
VEHICLE	
Rocket Skin Sections	249.2
Thermal Shields	27.0
WIFF Vacuum Door	38.2
Vacuum Bulkhead	13.5
Pressure Bulkhead	13.5
Ballast allotment	15.0
SPARCS Mass Sensor	0.8
TOTAL VEHICLE WEIGHT	367.2
TOTAL EXPERIMENT AND VEHICLE	551.7

TABLE 2-4 MASS MOMENTS/PRODUCTS OF INERTIA ABOUT EXP. CG			
AXIS	X	Y	Z
X	11.7	-2.0	0
Y	-2.0	241	0
Z	0	0	243
SI UNITS $Kg\text{-}M^2$			
NOTE: WIFF Vacuum Door Assembly included in these calculations.			

3.0 POINTING REQUIREMENTS

The SPARCS pointing accuracy must be within one arc-minute of the sun center. The pointing stability must not exceed a peak-to-peak error value of one-half arc-second in the pitch and yaw axis with a maximum roll rate of 0.2 arc-second per second about the roll axis. Absolute roll angle orientation will be specified at the time of flight and needs an angular positioning accuracy of ± 10 degrees.

4.0 LAUNCH WINDOWS AND REQUIREMENTS

Launch window is mid-April to end of August, and within one hour of local Noon (solar meridian transit).

5.0 MISSION SUCCESS CRITERIA

The primary purpose of this flight is to obtain extremely high spatial resolution soft X-ray images of the solar corona. The design goal of the TXI telescope is 0.25-.5 arc-second image quality. The exposure duration which is needed to record an image depends upon the solar activity level on the day of flight and upon the X-ray reflectivity of the mirrors and transmission of the filters (throughput). Under ideal conditions we may obtain images of the bright active region cores in a 1 second integration time. Under worst case conditions, we may need up to 30 seconds for an acceptable exposure.

The second purpose is to provide an in-flight calibration of the NASA TRACE satellite. We have selected the appropriate wavelengths to provide this calibration. The telescope design has been described in section 2.3.2.

5.1 Maximum Success Criteria

This flight's maximum success criterion is to achieve a full 430 seconds of stable solar pointing at the selected solar coordinates above an altitude of 110 kilometers. This will allow sufficient frames to be exposed onto the flight detectors based on an experiment initiation signal at 105 seconds. This permits the exposure sequences shown in Appendices A and B.

5.2 Minimum Success Criteria

The flight's minimum success criterion is to achieve 300 seconds of stable solar pointing at the selected solar coordinates above an altitude of 110 kilometers. This will allow a mimimun program to be carried out. The experiment has a redundant manual override capability which can be used if the flight experiences problems or the flight time is projected to be shorter than 400 seconds. This allows selection of the prime flight exposures onto our detectors, based on an experiment initiation signal at 90 seconds or a manual override command. Also we must receive a high quality T/M signal over this length of time.

5.3 Exposure Sequence

The TXI detector flight exposure sequence is listed in Appendix A.

The Calibration detector flight exposure sequence is listed in Appendix B.

6.0 SUPPORT REQUIREMENTS

6.1 Instrumentation

One PCM telemetry unit configured to interface per our drawing number TXI-5100. This PCM unit's configuration and requirements will be specified at our upcoming working meeting at NASA-WIFF, currently schedule for 27 Febuary 1997. A TV transmitter and receiver are required to broadcast our Hα video TV signal in real time. Two 10 mega-bit channels are required for the prime science. We also request that a TV monitor displaying our Hα video be located at the SPARCS control station, and room be provided for positioning our GSE for both the TXI and XUV recording and display.

6.2 Vehicle

A Mark 80-boosted Black Brandt vehicle with an S-19 ascent stage is requested. This vehicle, with its associated launch support and the launch rail, is expected to be provided.

6.3 Guidance

The pointing and stabilization requirements are specified in Section 3.0. The experiment has been configured to attach a SPARCS-MASS sensor directly to the vehicle for coarse solar acquisition and a LISS sensor attached directly to the optical bench for fine control. Also a SPARCS RIG is required for roll stabilization.

6.4 Mechanical

We plan to integrate and test the experiment at WSMR. We will have portable optical measuring equipment at WSMR to evaluate alignment and telescope focus. We expect all fixtures required during integration and flight testing to be available at WSMR, such as vibration, dynamic balance, etc. Experimenter personnel will be available to aid in these tasks. Also, we anticipate the need to use the SPARCS group's collimation telescope and Heliostat during the optical alignent and verification testing.

6.5 Recovery

The experiment employs CCD cameras and onboard memory for storage of scientific data. The CCD is sensitive to noise from excessive heating, therefore the vehicle has been thick anodized to minimize solar heating during the recovery phase. Also, the WIFF vacuum door will be closed during re-entry heating to keep dirt, brush, etc., from contaminating the experiment on impact. We request helicopter conveyance for two experiment team members to recover the payload quickly and survey possible damage.

6.6 Batteries

Battery power during flight is being provided by the SPARCS TM unit. Our power requirements are 28 volts with an average current draw of 15 amps, with peak draw of 20 amps for 1 sec.

6.7 Vacuum Station

A turbomolecular vacuum pumping system with roughing pump will be required for experiment evacuation at various WSMR test facilities, i.e., vibration qualification. The system must be appropriately valved to allow switching between pumps with a pumping line valve allowing fine control of the pumping speed and back-filling the system with dry nitrogen. The system employed during our NIXT flights is acceptable.

6.8 Rail Positioning

The rail position will be as shown in figure 2.1.

6.9 Special Considerations

The experimenter plans to provide all equipment (including spare parts) necessary to test, operate and evaluate experiment performance. The only specialized facility required is a collimator with projection target for CCD focussing.

7.0 FLIGHT QUALIFICATION AND/OR OPERATION STATUS OF EXPERIMENT SUB SYSTEMS

The TXI experiment will be tested to the NASA requirements for a new payload. We request that all this testing be performed at the WSMR test facilities. We will provide the necessary manpower to support the experiment testing activities.

8.0 FIELD OPERATIONS

8.1 WSMR ACTIVITIES

Our present plans call for the experiment to arrive at WSMR, starting in May-June 1998 to begin the flight test program. We anticipate this activity to take 10 working days.

If sucessful, then we would plan to proceed directly to its first flight.

8.1.1 Flight Checkout Procedure

The TXI experiment has multiple X-ray imaging telescopes, all having narrow band prefilters sealing their apertures. A functional checkout of the X-ray optical performance cannot be performed at WSMR. This is because a collimated X-ray source is unavailable. Our testing and evaluation for flight will be as follows:

1. Test electronics for correct operation through telemetry and GSE control.

2. Verify position of optical focus by making non-X-Ray detector images. This also checks detector operation and image processing.

3. Examine prefilters to assure blemish* free state.

4. Verify vacuum integrity of vehicle.

5. Verify filter status via light leak diodes.

* The prefilters must attenuate the solar spectrum by 10^{-4} (focal plane filter must be 10^{-8}). There cannot be any flaking of the coating or pinholes in the filter substrate film.

8.1.2 Flight Operations

Blockhouse LC36 Area

Smithsonian GSE display equipment will interface to the Lockheed ITS console. Most of the pre-flight check out will take place in this configuration.

Equipment needed:

1. One 8 channel Brush recorder.

2. Four 10 bit digital word displays.

ASCL LC-35

Used during the flight and pre launch telemetry checkout. The following equipment will be needed:

1. Command Console.

2. TV monitor displaying experiment Hα video signal.

3. One 8 channel Brush recorder.

4. One 10 bit word selector, with both analog and digital display capability.

5. Space for experiment VHS video recorder and monitor.

6. TV monitor displaying experiment housekeeping.

7. Quick look GSE for science data.

8.1.3 Pre-Flight and Flight Day Activities

In the evening before launch day, a series of exposures will be taken using our illumination system to ensure prefilter performance. Acceptable exposures are required for approval to launch the following day. An acceptable exposure means no indication of a light leak as detected by our detectors, ie increased counts.. The general flight-day checkout procedure is shown in table 8-1.

TABLE 8-1 GENERAL FLIGHT DAY CHECKOUT PROCEDURE	
TIME	EVENT
T-240 MIN	Begin Experiment Evacuation.
T-90	All personnel at their stations.
T-80	Perform Tower Functional Checkout Procedure.
T-60	Close Vacuum Valve.
T-58	Vent Vacuum Probe.
T-59	Verify Vacuum Pressure Steady.
T-30	Remove Vacuum Probe (now or as close to launch as possible).
T-25	O.K. to Launch.
T-15	Verify All Records Running Properly.
T-5	Experiment and T-M on External Power.
T-4	Verify GSE Telemetry Correct.
T-0	Launch.
T + 30	Verify vacuum valve open
T + 50	Hα Camera on
T + 69	Verify Hα Camera image
T + 89	Verify detectors on
T + 95	Verify Pointing Coordinates using Hα Camera Image.
T + 90 - End of Data Taking	Verify Pointing Stability and detector Sequencing.
T + (IF Required)	*Send Abort and manual Mode Commands as Required.
T +TBD	Verify WIFF Vacuum Door Closed.
T + TBD	Verify Experiment Power Off.
* Sent only if large pointing excursion or camera malfunction occurs.	

APPENDIX A

Time into flight* (Seconds)	Wavelength (Angstrom)	Exposure Time (Seconds)
T+105	171	20
130	171	10
145	175	10
160	178	10
185	180	3
190	182	10
205	188	10
220	192	10
235	195	10
250	195	3
255	195	10
270	203	30
305	211	10
320	203	10
335	195	10
350	192	10
365	188	10
380	175	3
395	175	3
400	175	3
405	175	3

* Times shown are preliminary and are subject to change based on NASA's Ballist analysis (Time vs. Altitude).

APPENDIX B

Time into flight* (Seconds)	Wavelength (Angstrom)	Exposure Time (Seconds)
T+105	171	10
120		10
135		30
170	195	10
185		30
220	284	10
235	188	30
270	304	10
285		30
320	171	10
335	195	10
350	284	10
365	171	10
380	195	10
395	171	10
410	195	10
Repeat last 2 steps until reentry		

NOTE: We are allowing 5 seconds in between exposures for readout. This time may be adjusted, based on actual operation.

* Times shown are preliminary and are subject to change based on NASA's Ballist analysis (Time vs. Altitude).

APPENDIX C

SAO DRAWING NUMBERS

TXI- 5100 - Titled: TXI - System Diagram

TXI- TBD - Titled: TXI - External Cabling Diagram

REFERENCES

1. Conrady, A.E. 1957, "Applied Optics and Optical Design" (Dover).

2. Thompson, K.P. 1980, Ph.D. Thesis, Univ. of Arizona.

3. Barbee, T.W., Jr., S. Mrowka, and M.C. Hettrick 1985, Appl. Opt., 24, 883.

4. Rosner, R., L. Golub, and G.S. Vaiana 1985, Ann. Rev. Astron. and Astryphy (in press).

5. Henry, J.P., E. Spiller and M. Weisskopf 1982, Appl. Phys. Lett., 40, 27.

6. Golub, L. 1984, Adv. Space Res., 4, 75.

7. Antonucci, E., R. Rosner and K. Tsinganos 1985, Ap.J. (in press).

8. Golub, L. 1980, Phil. Trans. R. Soc. London A, 297, 595.

9. Golub, L., E. Spiller, R.J. Bartlett, M.P. Hockaday, D.R. Kania, W.J. Trela and R. Tatchyn, 1984, Appl. Opt., 23, 3529.

NIXT PAPERS

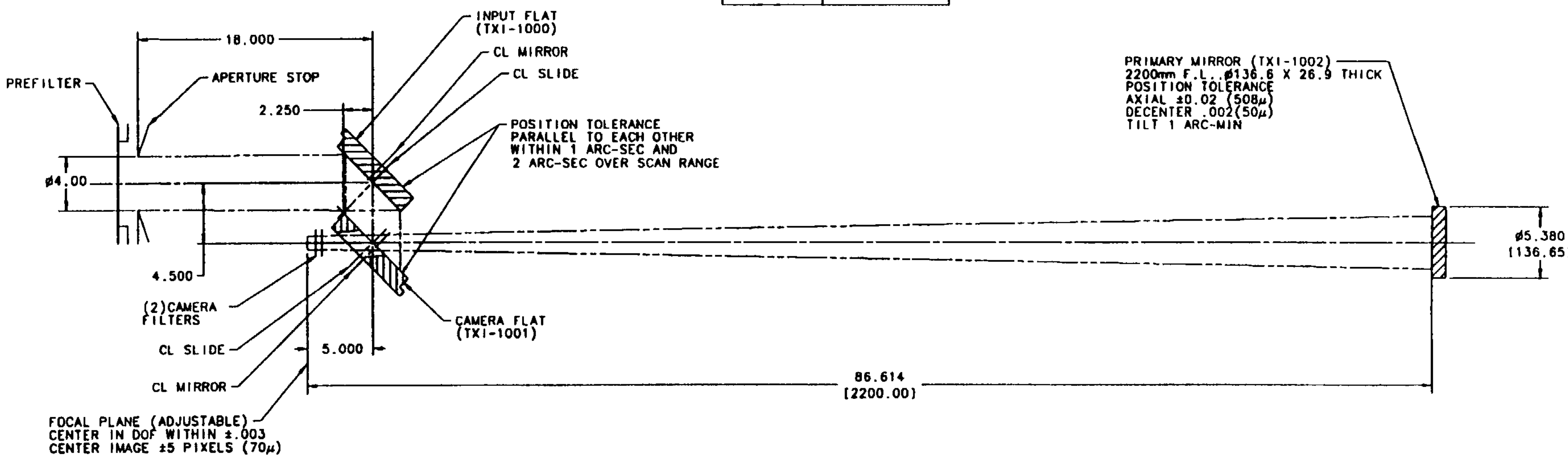
1. Spiller, E., and L. Golub, "Fabrication and Testing of Large Area Multilayer Coated X-ray Optics".

2. Golub, L., G. Nystrom, E. Spiller and J. Wilczynski, "Construction of a Multilayered X-ray Telescope for Solar Coronal Studies from Space".

3. Golub, L., G. Nystrom, E. Spiller, J. Wilczynski, P. Takacz, and C. Welch, "X-ray/EUV optics for Astronomy, Microscopy, Polarimetry and Projection Lithography".

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	1	INITIAL ISSUE		

MONOCHROMATOR TABLE	
GRAZING ∡	WAVELENGTH
39.5°	171 A°
45°	190 A°
51.8°	211 A°
54.9	220 A°



NOTES:

1. MATERIAL: N/A
2. FINISH: N/A
3. SYSTEM f NUMBER =21.635, DEPTH OF FIELD ± .0119 (302.89μ).
4. OPTICAL IMAGERY, SEE ZEEMAX FILE, TITLED X-RAY SCAN.

REMOVE BURRS AND BREAK SHARP EDGES
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS DECIMALS ANGLES
MATL: 1 FIN: 2
NEXT ASSY N/A

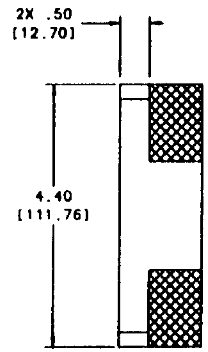
SMITHSONIAN ASTROPHYSICAL OBSERVATORY
CENTRAL ENGINEERING CAMBRIDGE MA.

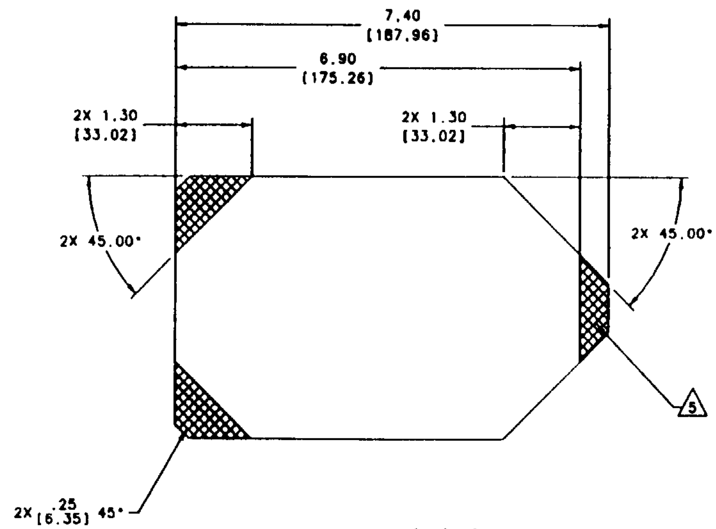
OPTICAL SCHEMATIC
TXI

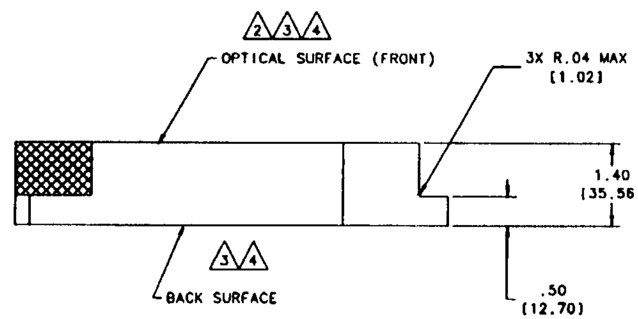
SIZE	CODE IDENT NO.	DWG NO.	REV
D	50944	TXI-002	1

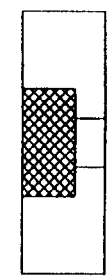
SCALE 1/4 IDEAS V6.i SHEET 1 OF 1

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	2	REVISED PER DCR # 01		









NOTES:

1. MATERIAL: FUSED SILICA, PREMIUM GRADE.

2. FINISH: ALL SURFACE FINISHES PER MIL-O-13830. OPTICAL SURFACE SHALL BE SUPER POLISHED TO A REQUIRED ROUGHNESS OF 3A° WITH A GOAL OF 1A°. BACK SURFACE, POLISH TO A SCRATCH/DIG TOLERANCE OF 40-20. ALL OTHER SURFACES TO BE MEDIUM GROUND TO AN 80/50 TOLERANCE.

3. SURFACE FIGURE: THE OPTICAL SURFACE TO BE FLAT AND SMOOTH TO A PEAK TO VALLEY TOLERANCE OF 1/40λ WHEN MEASURED AT 6328A° (STANDARD ZYGO INTERFEROMETER). EDGE EFFECTS CAN BE MASKED UP TO 4mm FROM EDGES. THE BACK SURFACE TO BE 1/2 TO 1/4λ WHEN MEASURED AS ABOVE.

4. THE OPTICAL SURFACE AND BACK BACK SURFACE TO BE PARALLEL TO EACH OTHER WITHIN 2 ARC-MINUTES.

5. SURFACES INDICATED BY CROSSHATCHING TO BE HYDROSULFURIC ACID ETCHED AFTER INITIAL OPTICAL FABRICATION AND PRIOR TO FINAL SURFACE FIGURING.

6. ALL EDGES TO HAVE EITHER A 1mm RADIUS OR A 1mm X 45° CHAMFER AT OPTICAL MANUFACTURERS DISCRETION.

7. ESTIMATED MASS IS 1.38 Kg.

8. DIMENSIONS IN BRACKETS ARE MILLIMETERS.

9. COATINGS: NONE

REMOVE BURRS AND BREAK SHARP EDGES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON: FRACTIONS ± · DECIMALS .XX ± .01 .XXX ± .005 · ANGLES ± .25°

MACH. FIN: N/A

MAT'L: 1 · FIN: 2

NEXT ASSY: TX1-501

DR M. HONDA · DATE 09-30-00 · CHK · DATE 12/13/00

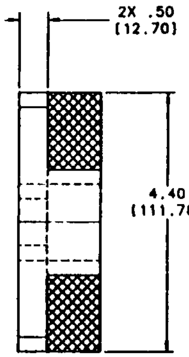
SMITHSONIAN ASTROPHYSICAL OBSERVATORY
CENTRAL ENGINEERING · CAMBRIDGE MA.

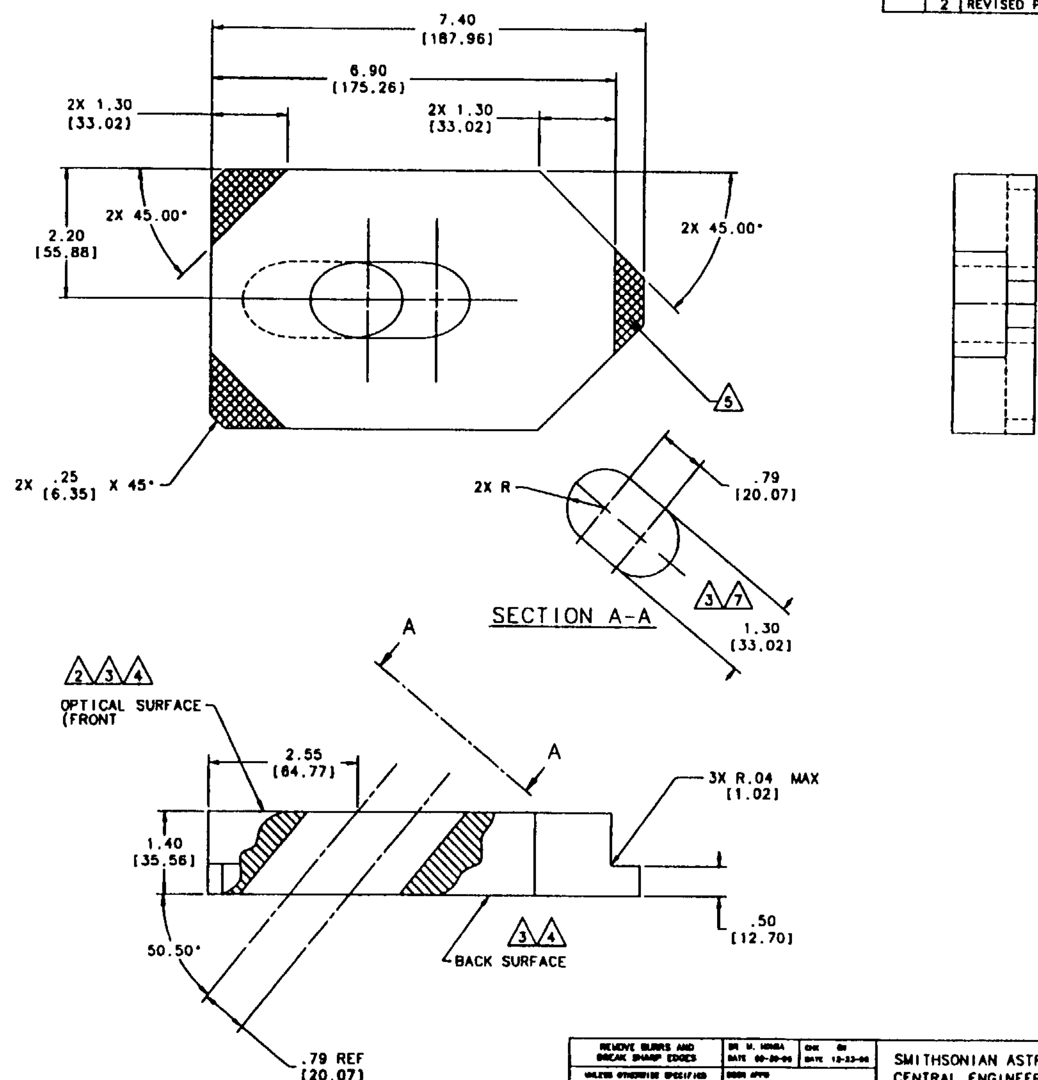
INPUT FLAT, FLIGHT

SIZE	CODE IDENT NO.	DWG NO.	REV
D	50944	TX1-1000	2

SCALE 1/1 · IDEAS MS 3.0 · SHEET 1 OF 1

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	2	REVISED PER DCR # 01		





NOTES:

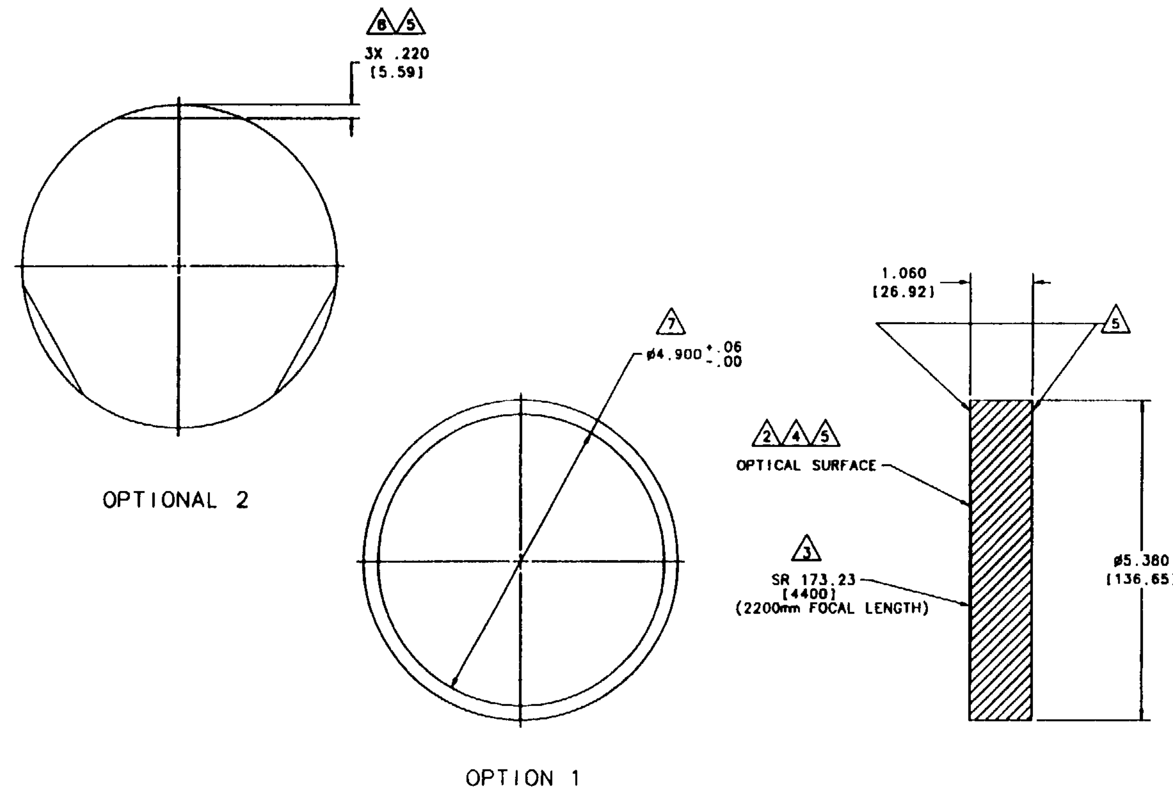
1. MATERIAL: FUSED SILICA, PREMIUM GRADE.
2. FINISH: ALL SURFACE FINISHES PER MIL-O-13830. OPTICAL SURFACE SHALL BE SUPER POLISHED TO A REQUIRED ROUGHNESS OF 3A° WITH A GOAL OF 1A°. BACK SURFACE, POLISH TO A SCRATCH/DIG TOLERANCE OF 40-20. ALL OTHER SURFACES TO BE MEDIUM GROUND TO AN 80/50 TOLERANCE.
3. SURFACE FIGURE: THE OPTICAL SURFACE TO BE FLAT AND SMOOTH TO A PEAK TO VALLEY TOLERANCE OF 140λ WHEN MEASURED AT 6328A° (STANDARD ZYGO INTERFEROMETER). EDGE EFFECTS CAN BE MASKED UP TO 4mm FROM EDGES AND 1 mm AROUND HOLE. THE BACK SURFACE TO BE 1/2 TO 1/4λ WHEN MEASURED AS ABOVE.
4. THE OPTICAL SURFACE AND BACK BACK SURFACE TO BE PARALLEL TO EACH OTHER WITHIN 2 ARC-MINUTES.
5. SURFACES INDICATED BY CROSSHATCHING TO BE HYDROSULFURIC ACID ETCHED AFTER INITIAL OPTICAL FABRICATION AND PRIOR TO FINAL SURFACE FIGURING.
6. ALL EDGES TO HAVE EITHER A 1mm RADIUS OR A 1mm X 45° CHAMFER AT OPTICAL MANUFACTURERS DISCRETION.
7. 1.40 (35.56mm) DIMENSION APPLIES AT OPTICAL SURFACE. A SLIGHT TAPER IS ALLOWABLE LEAVING A LARGER DIMENSION AT THE BACK SURFACE.
8. ESTIMATED MASS IS 1.22 Kg.
9. DIMENSIONS IN BRACKETS ARE MILLIMETERS.
10. COATINGS: NONE

REMOVE BURRS AND BREAK SHARP EDGES
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON FRACTIONS DECIMALS ANGLES
MACH. FIN: N/A
MAT'L: 1 FIN: 2
NEXT ASSY TX1-501

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
CENTRAL ENGINEERING CAMBRIDGE, MA.

CAMERA FLAT, FLIGHT

SIZE D | CODE IDENT NO. 50944 | DWG NO. TXI-1001 | REV 2
SCALE 1/1 | IDEAS MS3 | SHEET 1 of 1



NOTES:

1. MATERIAL: FUSED SILICA, PREMIUM GRADE.
2. FINISH: ALL SURFACE FINISHES PER MIL-O-13830. OPTICAL SURFACE SHALL BE SUPER POLISHED TO A REQUIRED ROUGHNESS OF 3A° WITH A GOAL OF 1A°. BACK SURFACE, POLISH TO A SCRATCH/DIG TOLERANCE OF 40-20. ALL OTHER SURFACES TO BE MEDIUM GROUND TO AN 80/50 TOLERANCE.
3. THE MIRRORS FOCAL LENGTH SHALL BE 2200mm ±3mm.
4. SURFACE FIGURE: THE OPTICAL SURFACE TO BE SPHERICAL WITH A MAXIMUM PEAK TO VALLEY DEVIATION FROM AN IDEAL SURFACE OF 1/40λ WHEN MEASURED AT 6328A° (STANDARD ZYGO INTERFEROMETER).EDGE EFFECTS CAN BE MASKED UP TO 2mm FROM EDGES.THE BACK SURFACE TO BE 1/2 TO 1/4λ WHEN MEASUREDAS ABOVE.
5. THE BACK SURFACE AND FRONT FLAT SURFACE AREA MUST BE PARALLEL TO EACH OTHER AND PERPENDICULAR TO THE SPHERICAL GENERATION AXIS WITHIN 2 ARC-MINUTES.
6. ALL EDGES TO HAVE EITHER A 1mm RADIUS OR A 1mm X 45° CHAMFER AT OPTICAL MANUFACTURERS DISCRETION.
7. DIAMETER OF SPHERICAL SURFACE.
8. OPTION 2, FIGURE ENTIRE SURFACE THEN GRIND 3 FLATS AS SHOWN.
9. ESTIMATED MASS IS 1.04 Kg.
10. DIMENSIONS IN BRACKETS ARE MILLIMETERS.
11. COATING: NONE

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	1	INITIAL ISSUE		

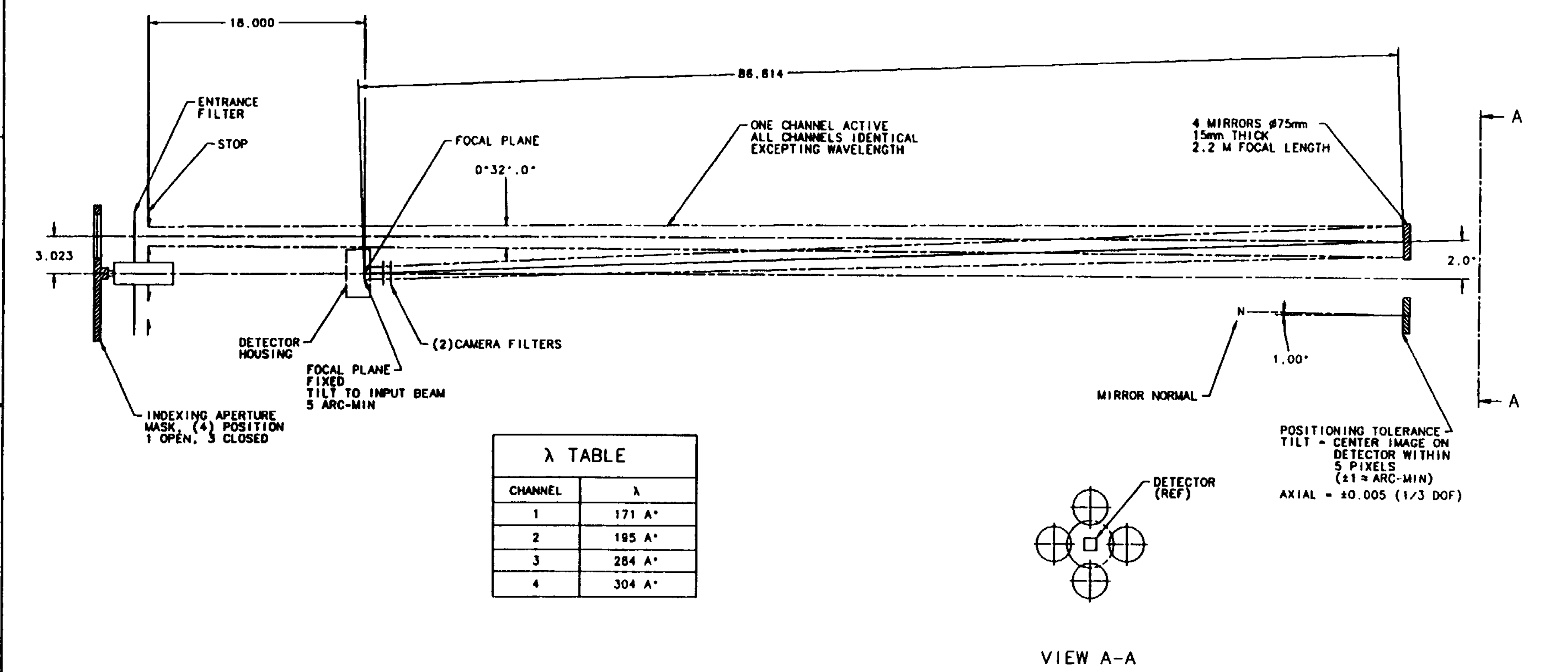
SMITHSONIAN ASTROPHYSICAL OBSERVATORY
CENTRAL ENGINEERING

PRIMARY MIRROR

SIZE	CODE IDENT NO.	DWG NO.	REV
D	50944	TXI-1002	1

SCALE 1/1 IDEAS MS 3.0 SHEET 1 OF 1

NEXT ASSY TXI-502



λ TABLE

CHANNEL	λ
1	171 A°
2	195 A°
3	284 A°
4	304 A°

NOTES:

1. MATERIAL: N/A
2. FINISH: N/A
3. DEPTH OF FIELD = ±.017 (433μ)

REVISIONS: 1 INITIAL ISSUE

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
CENTRAL ENGINEERING

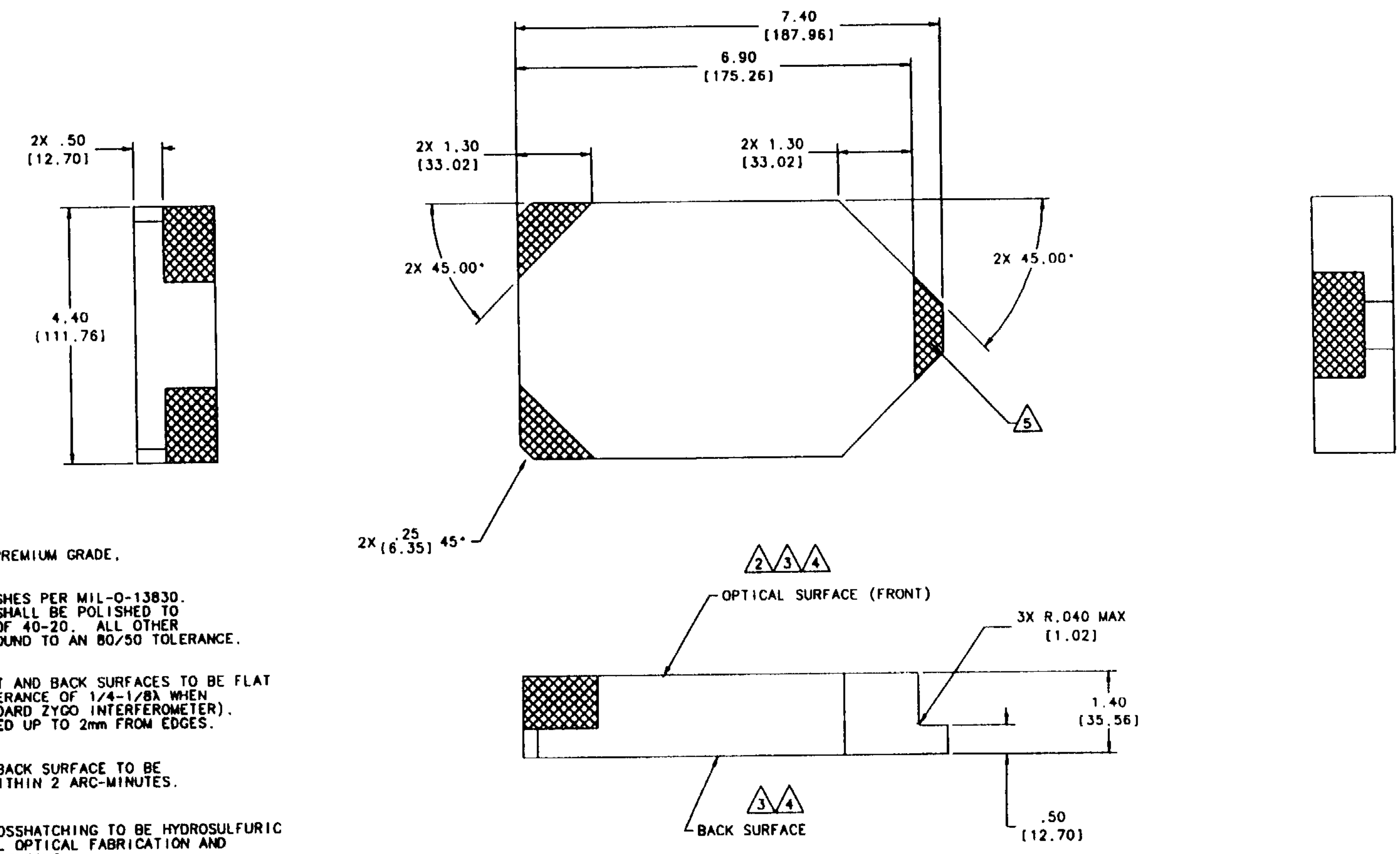
OPTICAL SCHEMATIC CALIBRATION

D | 50944 | TXI-003 | REV 1

SCALE 1/4 | IDEAS MS3 | SHEET 1 of 1

NEXT ASSY N/A

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	1	INITIAL ISSUE		



NOTES:

1. MATERIAL: FUSED SILICA, PREMIUM GRADE.
2. FINISH: ALL SURFACE FINISHES PER MIL-O-13830. FRONT AND BACK SURFACES SHALL BE POLISHED TO A SCRATCH/DIG TOLERANCE OF 40-20. ALL OTHER SURFACES TO BE MEDIUM GROUND TO AN 80/50 TOLERANCE.
3. SURFACE FIGURE: THE FRONT AND BACK SURFACES TO BE FLAT AND SMOOTH TO AN RMS TOLERANCE OF 1/4-1/8λ WHEN MEASURED AT 6328A° (STANDARD ZYGO INTERFEROMETER). EDGE EFFECTS CAN BE MASKED UP TO 2mm FROM EDGES.
4. THE OPTICAL SURFACE AND BACK SURFACE TO BE PARALLEL TO EACH OTHER WITHIN 2 ARC-MINUTES.
5. SURFACES INDICATED BY CROSSHATCHING TO BE HYDROSULFURIC ACID ETCHED AFTER INITIAL OPTICAL FABRICATION AND PRIOR TO FINAL SURFACE FIGURING.
6. ALL EDGES TO HAVE EITHER A 1mm RADIUS OR A 1mm X 45° CHAMFER AT OPTICAL MANUFACTURERS DISCRETION.
7. ESTIMATED MASS IS 1.38 Kg.
8. DIMENSIONS IN BRACKETS ARE MILLIMETERS.
9. APPLY AN OPTICAL COATING OF ALUMINUM WITH AN OVERCOAT OF 200-300A° OF SILICON DIOXIDE OR SILICON MONOXIDE.

REMOVE BURRS AND BREAK SHARP EDGES
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON: FRACTIONS ± ; DECIMALS .XX ± .01, .XXX ± .005; ANGLES ± .25°
MACH. FIN: N/A
MAT'L: 1 FIN: 2
NEXT ASSY TX1-501

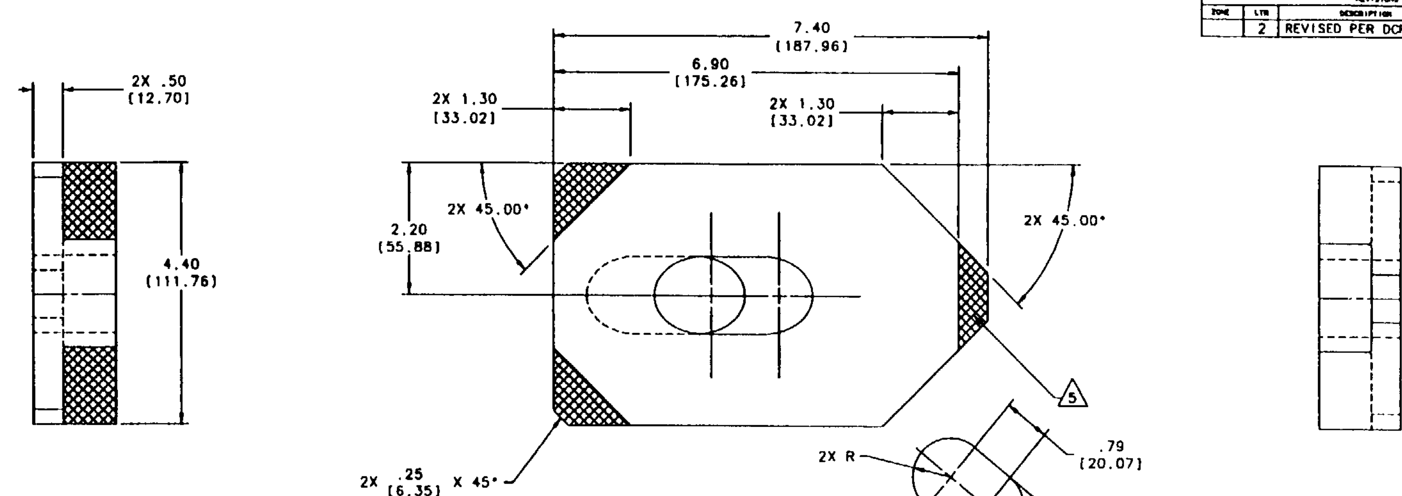
DR M. HONDA DATE 08-30-94

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
CENTRAL ENGINEERING CAMBRIDGE, MA.

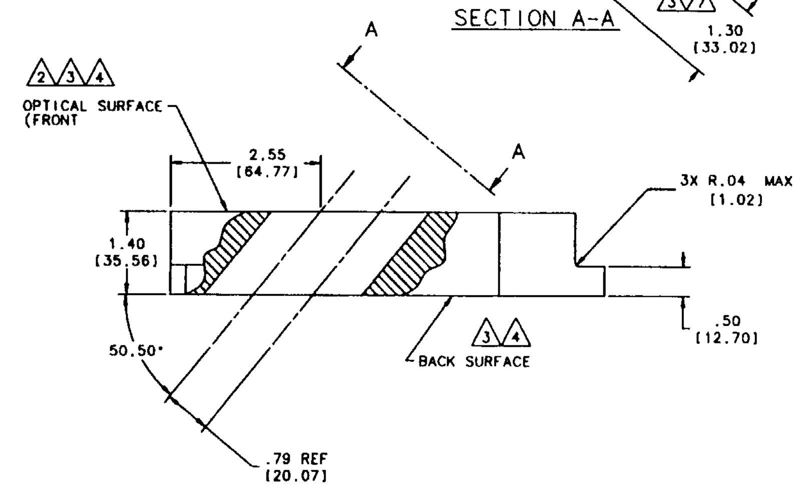
INPUT FLAT, TEST

SIZE	CODE IDENT NO.	DWG NO.	REV
D	50944	TX1-1003	1

SCALE 1/1 IDEAS MS 3.0 SHEET 1 OF 1



SECTION A-A



NOTES:

1. MATERIAL: FUSED SILICA, PREMIUM GRADE.
2. FINISH: ALL SURFACE FINISHES PER MIL-O-13830. FRONT AND BACK SURFACES SHALL BE POLISHED TO A SCRATCH/DIG TOLERANCE OF 40-20. ALL OTHER SURFACES TO BE MEDIUM GROUND TO AN 80/50 TOLERANCE.
3. SURFACE FIGURE: THE FRONT AND BACK SURFACES TO BE FLAT AND SMOOTH TO AN RMS TOLERANCE OF 1/4-1/8λ WHEN MEASURED AT 6328A° (STANDARD ZYGO INTERFEROMETER). EDGE EFFECTS CAN BE MASKED UP TO 2mm FROM EDGES AND 1 mm AROUND HOLE.
4. THE OPTICAL SURFACE AND BACK BACK SURFACE TO BE PARALLEL TO EACH OTHER WITHIN 2 ARC-MINUTES.
5. SURFACES INDICATED BY CROSSHATCHING TO BE HYDROSULFURIC ACID ETCHED AFTER INITIAL OPTICAL FABRICATION AND PRIOR TO FINAL SURFACE FIGURING.
6. ALL EDGES TO HAVE EITHER A 1mm RADIUS OR A 1mm X 45° CHAMFER AT OPTICAL MANUFACTURERS DISCRETION.
7. 1.40 (35.56mm) DIMENSION APPLIES AT OPTICAL SURFACE. A SLIGHT TAPER IS ALLOWABLE LEAVING A LARGER DIMENSION AT THE BACK SURFACE.
8. ESTIMATED MASS IS 1.22 Kg.
9. DIMENSIONS IN BRACKETS ARE MILLIMETERS.
10. APPLY AN OPTICAL COATING OF ALUMINUM WITH AN OVERCOAT OF 200-300A° OF SILICON DIOXIDE OR SILICON MONOXIDE.

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	2	REVISED PER DCR # 01		

REMOVE BURRS AND BREAK SHARP EDGES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON FRACTIONS ± DECIMALS .XX ± .01 .XXX ± .005 ANGLES ± .25°

MACH. FIN: N/A

MAT'L: 1 FIN: 2

NEXT ASSY TX1-501

DR M. HONDA DATE 09-20-00 CHK GH DATE 12-23-00

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
CENTRAL ENGINEERING
CAMBRIDGE, MA.

CAMERA FLAT, TEST

SIZE D CODE IDENT NO. 50944 DWG NO. TXI-1004 REV 2

SCALE 1/1 IDEAS MS3 SHEET 1 of 1

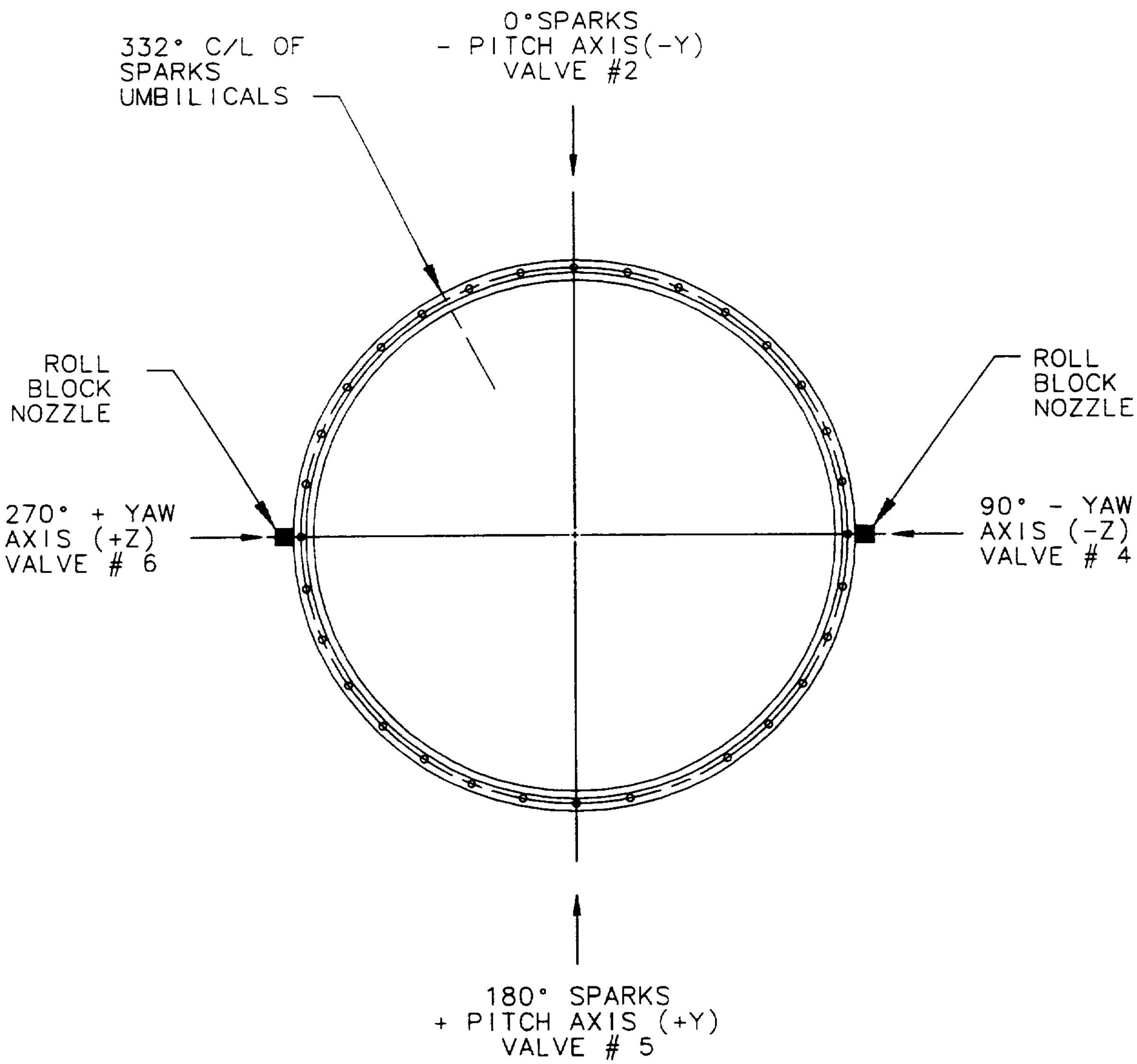


Figure 2-1.
TXI Angular Orientations WSMR-Tower

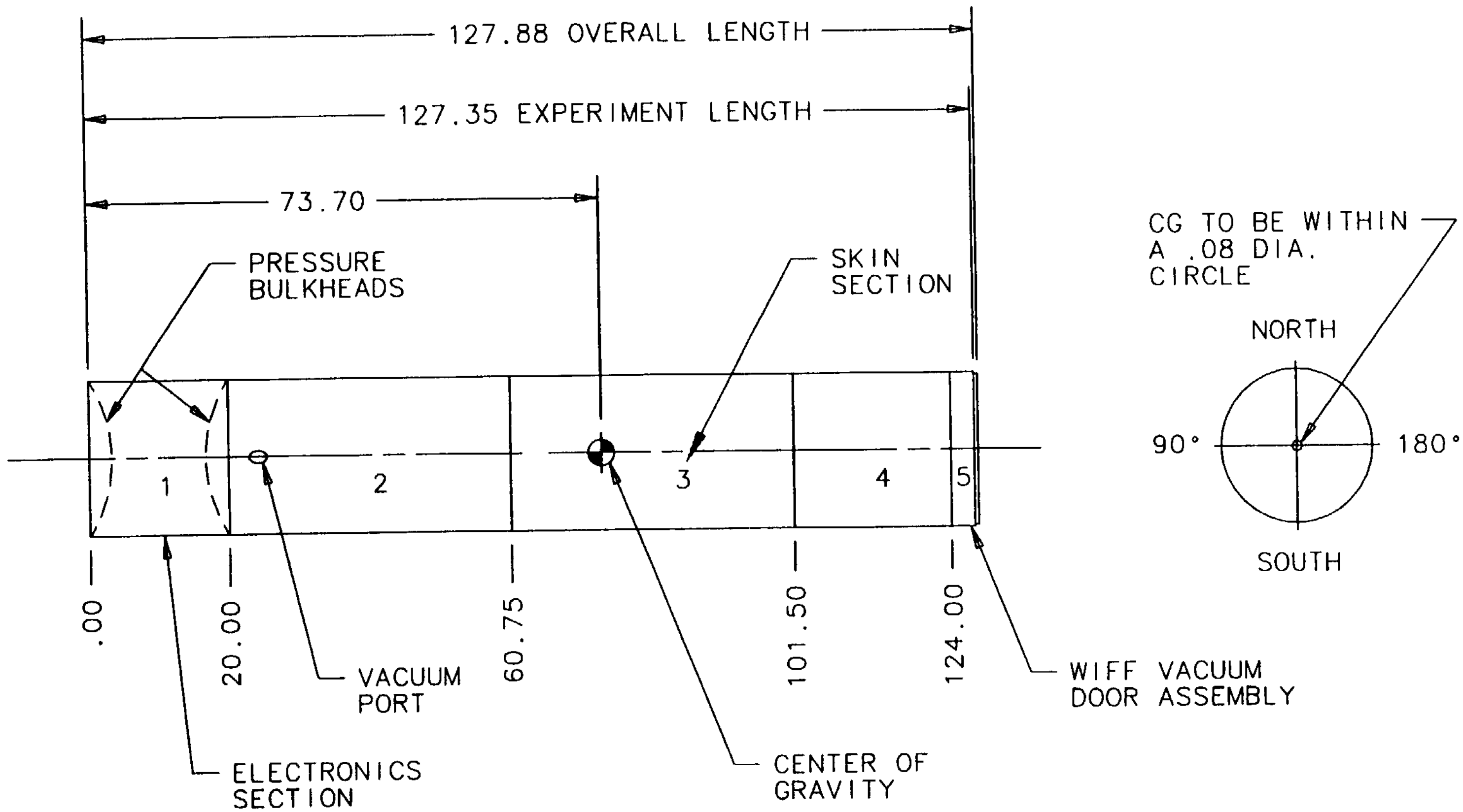


Figure 2-2.
TXI Center of Gravity Location